Operational Guidelines for the Field Test to Reduce Velocity Dealiasing Errors by Using a 2-D Velocity Dealiasing Scheme

W. David Zittel, Test Director

ROC, Applications Branch

1. Engineering Change Proposal to Reduce Velocity Dealiasing Errors by Using a 2-D Velocity Dealiasing Algorithm

This field test is authorized under the auspices of Test ECP-0511, FIELD TEST TO REDUCE VELOCITY DEALIASING ERRORS BY USING A 2-D VELOCITY DEALIASING SCHEME.

2. Background and Introduction

The current Weather Surveillance Radar-1988 Doppler (WSR-88D) utilizes two velocity dealiasing schemes, the Velocity Dealiasing Algorithm (VDA) and the Multiple Pulse Repetition Frequency (PRF) Velocity Dealiasing Algorithm (MPDA). The VDA primarily uses radial continuity, an average of nearby velocity neighbors, or an Environmental Wind Table (EWT) to help resolve winds exceeding the maximum unambiguous velocity (Nyquist Velocity, V_N) which for the WSR-88D is between 21 and 35 m s^{-1} for the following precipitation Volume Coverage Patterns (VCPs): VCPs 11, 12, 21, 211, 212, & 221 and the clear air VCP 32. The long-pulse clear air VCP 31 has a Nyquist velocity of about 8 m s^{-1}. The VDA can fail: 1) under strong shear conditions; 2) in velocity data with moving clutter; 3) in areas with weak echoes; 4) when the Nyquist velocity is much lower than the prevailing winds; or 5) where the values in the EWT are not representative of the local storm winds. The MPDA, fielded in 2004 as VCP 121, takes multiple scans of velocity data at the same elevation using up to three different PRFs. The utility of the MPDA in VCP 121 is limited during rapidly changing weather events because the additional scans required increases the volume scan time to nearly 6 minutes. VCP 121's utility is further diminished because it has only 9 unique elevation angles with which to interrogate storm structure.

This document provides an overview of a new two-dimensional velocity dealiasing algorithm currently under evaluation by the Radar Operations Center (ROC) and guidance to field sites as to how and when to use the 2-D velocity dealiasing algorithm which variously will be called VDEAL, 2D VDEAL, or 2D VELDEAL throughout this document. VDA refers to the legacy velocity dealiasing algorithm and MPDA refers to the Multiple PRF Dealiasing Algorithm.

3. Site Selection and Test Duration

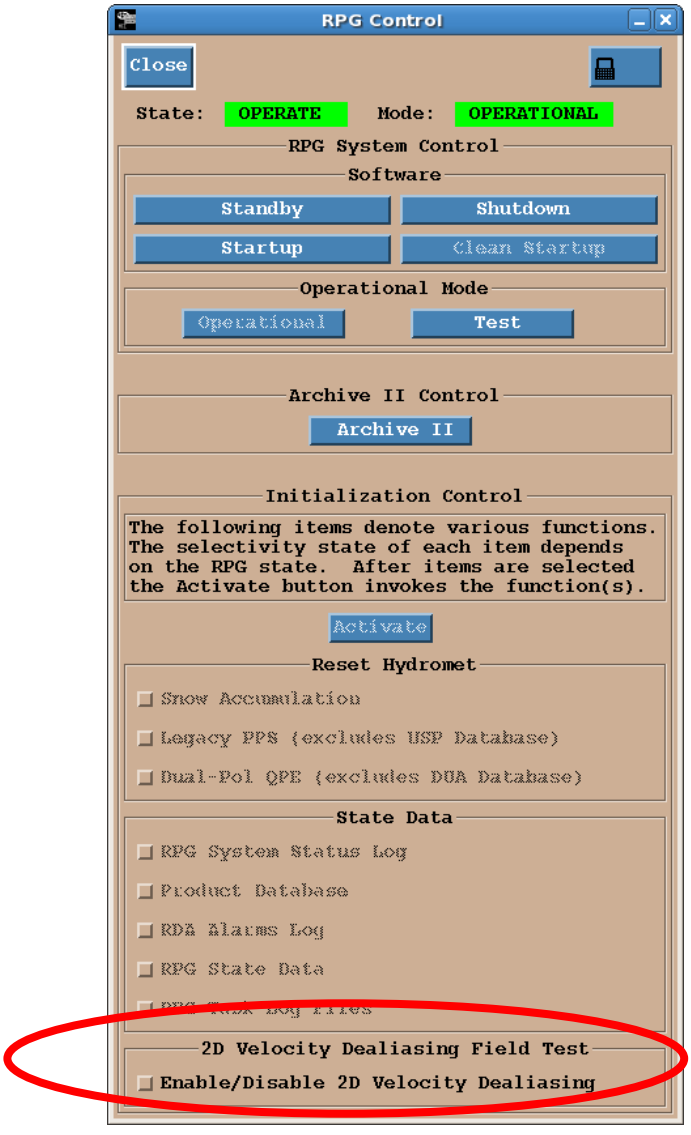
Independent testing of VDEAL by the ROC Applications Branch and by scientists at the National Severe Storms Laboratory (NSSL) showed VDEAL reduced velocity dealiasing errors for a wide range of weather events as compared to VDA. Because the greatest reduction occurred with large hurricanes, the field test focuses on coastal sites liable to have land-falling hurricanes. Mountainous sites are of great interest because of the channeling of air through passes. Continental interior sites provide the opportunity to document the performance in extratropical storms. The test will last for about 4 months from August 15, 2011 through December 2011 which will include much of the hurricane season.

Participating Sites by Region

Eastern	*Central*	*Western*	*Southern*
Burlington, VT	Des Moines, IA	Boise, ID	Brownsville, TX
Wilmington, NC	Goodland, KS	Great Falls, MT	Corpus Christi, TX
	Pueblo , CO		Key West, FL
			Lake Charles, LA
			Miami, FL
			Tallahassee, FL

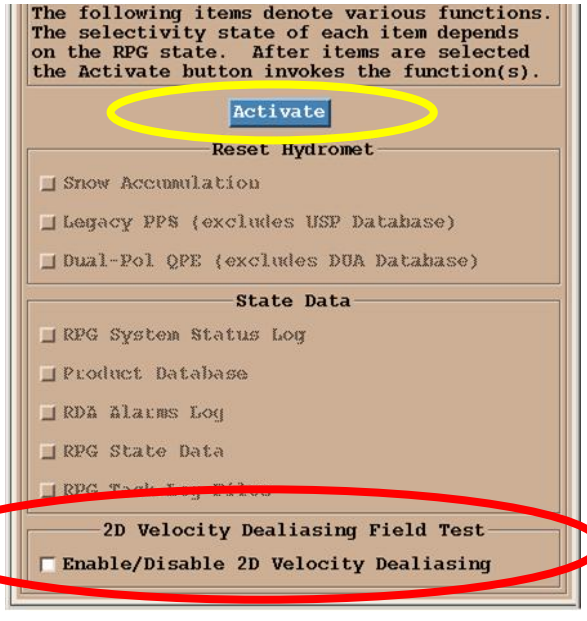
4. Activating/Deactivating the 2-D Velocity Dealiasing Algorithm (VDEAL)

Beginning with RPG Software Build 12 and higher, VDEAL is included as part of the software package but not accessible to field sites. Each site participating in the field test will be sent a modification kit with instructions on how to install and uninstall access to the VDEAL algorithm. The kit will provide an extra HCI task that allows the user to toggle the VDEAL algorithm on or off. By default, the legacy VDA remains the active algorithm. Figure 1 shows the HCI's RPG Control window with the 2D Velocity Dealiasing (VDEAL) toggle at the bottom.



Figures 1a (left) and 1b (below). The text to deactivate/activate the 2D dealiasing velocity algorithm is at the bottom of the RPG Control window (red ovals in Figures 1a & 1b). The text is black indicating that the button active. Clicking on the button turns it white (red oval) and the text in the blue Activate button turns white (yellow oval in Figure 1b).

Figure 1b truncated version of RPG Control window.



After clicking the 2D VDEAL toggle the Activate button is highlighted. Clicking on the Activate button causes a yellow Warning Popup box to open (Figure 1c below). Click on Yes to complete the change in velocity dealiasing algorithm.

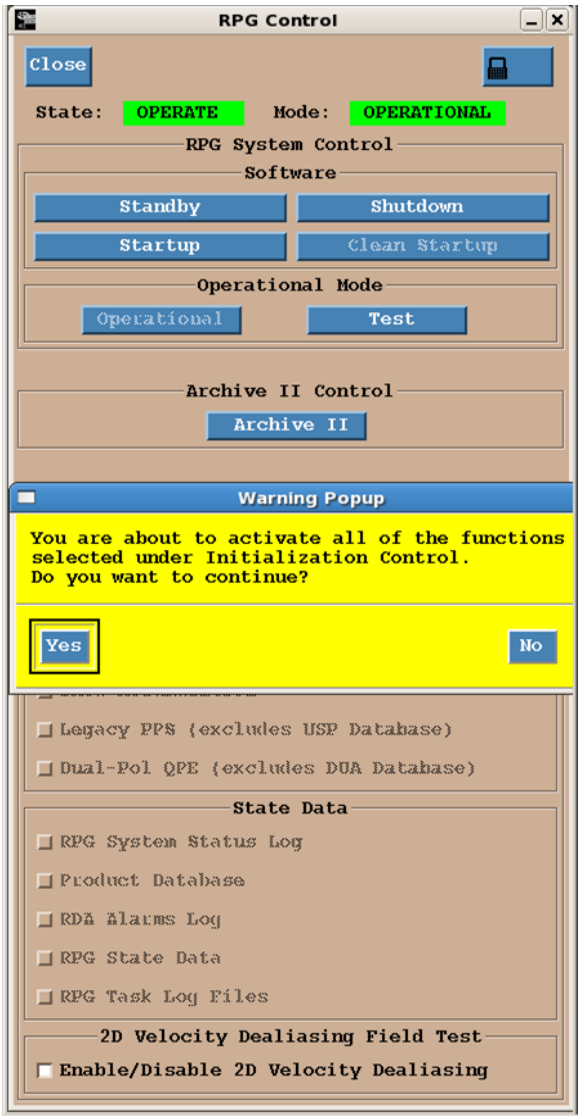


Figure 1c. RPG Control window with Warning Popup.

Note that the toggle switch itself does not indicate whether or not 2D VDEAL has been selected. Rather a message will be sent to the RPG Status line on the RPG Control window (Figure 2) indicating if 2D VELDEAL has been enabled or disabled. If disabled, the legacy VDA will be the default velocity dealiasing algorithm. Regardless of which algorithm has been selected, it becomes active only at the start of the next volume scan. The same message that shows up on RPG Control window's Status line is also entered into the RPG Status log (Figure 3).

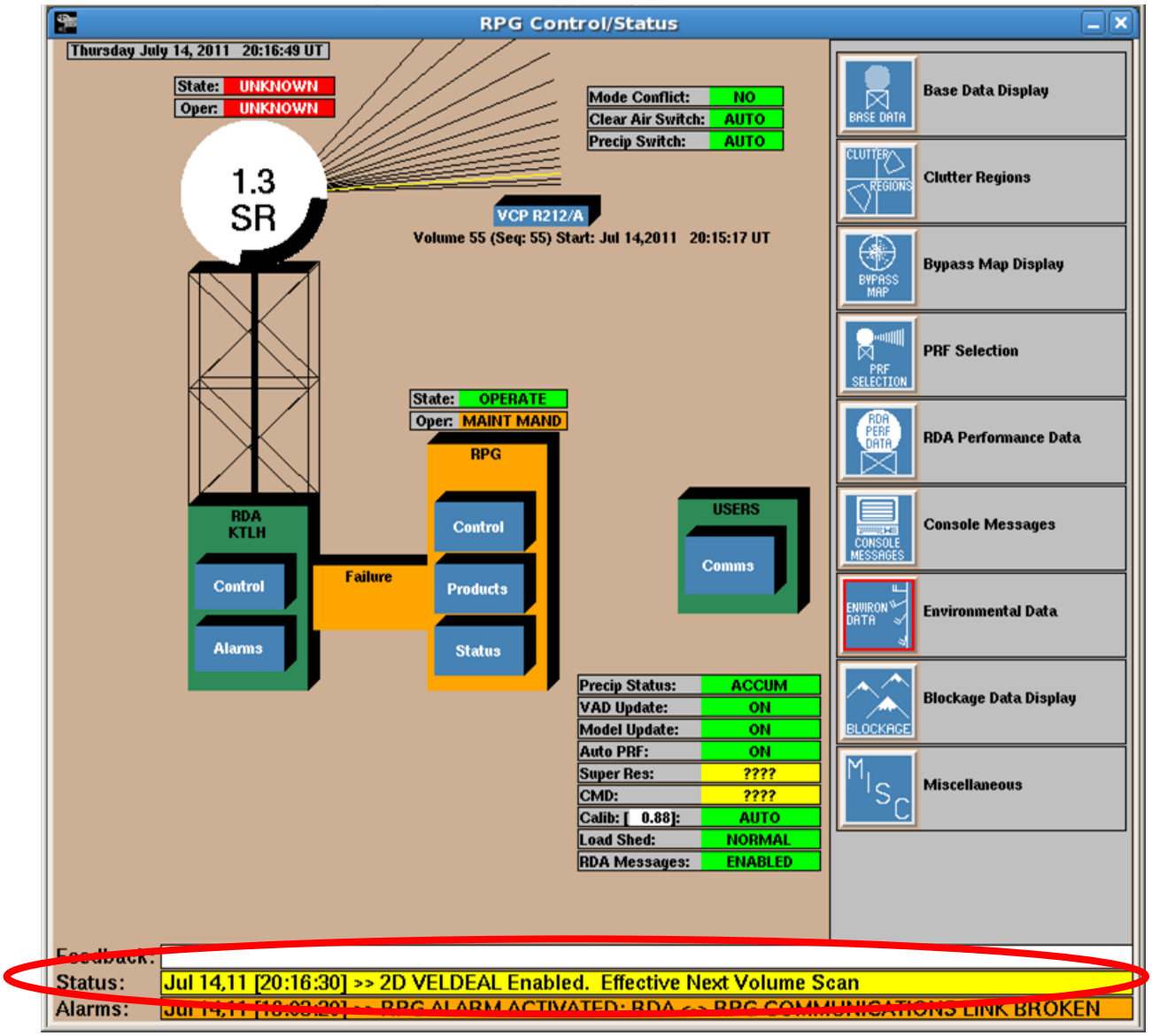


Figure 2. RPG Control/Status window shows that the 2D velocity dealiasing algorithm (VDEAL) has been enabled starting with the next volume scan (red oval).

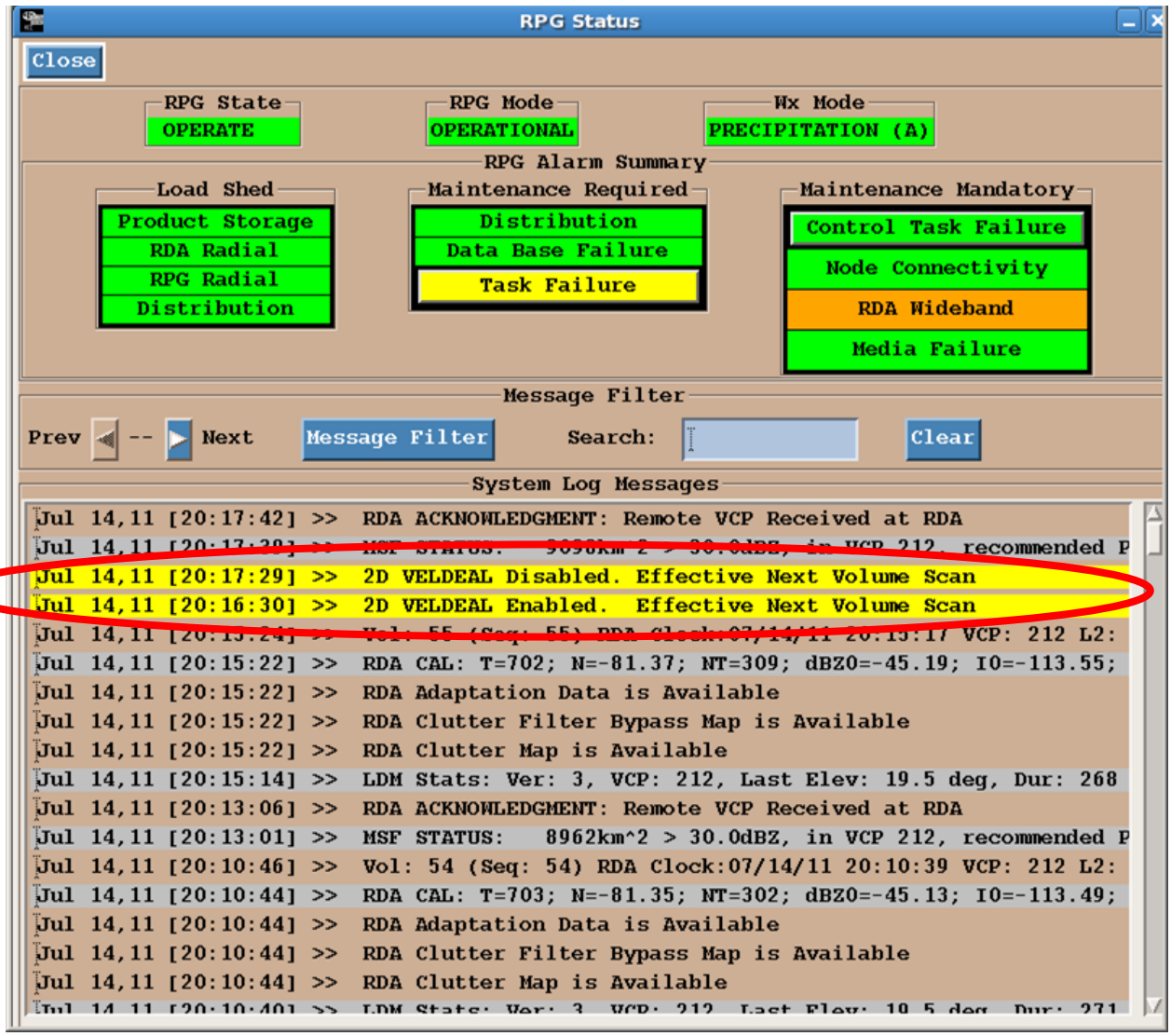


Figure 3. RPG Status window showing log entries that indicate the 2D velocity dealiasing algorithm was enabled at 20:16:30 and then disabled at 20:17:29 on July 14, 2011.

Additionally, besides the messages indicating if 2D VELDEAL (VDEAL) has been enabled or disabled, at the start of each volume scan the velocity dealiasing task will send one of the following three messages to the System Log indicating which dealiasing algorithm is being used:

Jul 21,11 [15:43:55] >> VELDEAL: 2D Velocity Dealiasing Algorithm Being Used

or

Jul 21,11 [18:10:48] >> VELDEAL: Velocity Dealiasing Algorithm Being Used

or

Jul 21,11 [19:18:13] >> VELDEAL: Multi-PRF Dealiasing Algorithm Being Used.

5. Theory of Operation

VDEAL is a two-dimensional velocity dealiasing scheme that is more robust than the current VDA. It works by simultaneously dealiasing all gates in an elevation scan using a least-squares approach to minimize the discontinuity caused by aliasing. Greater weight is given to velocity differences near zero or at multiples of $2V_N$ as well as velocity differences where the corresponding spectrum width values are low. For velocity fields with more than 40,000 bins, VDEAL will first find a coarse global dealiasing solution for the velocity field and then dealias sub-regions.

VDEAL develops its own internal wind profile to assist with dealiasing and, therefore, does not use the Environmental Wind Table. Because of this, on initial startup, velocity products from the 0.5 deg elevation may have dealiasing errors. Elevation angles above 0.5 deg can use the wind profile generated from the lowest elevation angle. VDEAL's internal wind profile is retained for one volume scan before it must be generated anew. Therefore, a user could alternate between VDEAL and VDA for sequential volume scans without negatively affecting the performance of VDEAL. VDEAL can be used by all VCPs except VCP 121. VDEAL does require a full scan of velocity data before it can complete its dealiasing which may result in a slight delay (~1-2 sec) in product availability.

6. Operational Guidance

The following material discusses various scenarios for using VDEAL, which volume coverage patterns (VCPs) can use it, and how it interacts with the PRF selection tool. Also mentioned is that VDEAL does not mitigate range folding and that it is CPU intensive.

6.1 Modes of Operation

Sites participating in the field test will have a great deal of latitude as to when to use VDEAL. Except for an initial check-out period we do not expect to contact sites to request they specifically activate VDEAL. Three possible scenarios might be to 1) turn on VDEAL and leave it on for the duration of the field test, 2) activate VDEAL for specific weather events such as a hurricane, or 3) toggle between the legacy VDA and VDEAL at regular intervals. Of course, a site may choose to blend the various scenarios.

6.1.1 VDEAL Continuously On

Using VDEAL continuously is the preferred mode for this field test. It maximizes exposure to the new dealiasing algorithm and ensures the algorithm is tested on a variety of weather events. VDEAL has been shown to reduce dealiasing errors in clear air long-pulse mode as well as precipitation and clear air short-pulse modes. Although a site won't be able to directly compare dealiasing results between the legacy VDA and VDEAL, it could monitor velocity products from adjacent sites experiencing the same kind of weather.

6.1.2 VDEAL Used for Specific Weather Events

VDEAL has been shown to be very effective at reducing or eliminating dealiasing errors for specific weather events. A site might opt to use VDEAL for specific weather events such as

storms with circulations, large scale events such as hurricanes and extratropical storms, or squall lines. A limitation with this approach is that the site won't be able to observe the performance of VDEAL on a more complete spectrum of weather events. Direct comparison with the legacy VDA isn't possible but, as with the previous operational mode, a site could look at adjacent sites for comparison.

6.1.3 VDEAL and VDA Used Alternately

Although it would require toggling each volume scan, a site could choose to alternate between VDEAL and VDA. While still not providing a direct side-by-side comparison, this approach would provide a site with a sense of the frequency of dealiasing errors between the two algorithms.

6.4 VDEAL and VCP Selection

The precipitation VCPS that can be used by VDEAL are (11, 12, 21, 211, 212, and 221). In clear-air mode, both VCPs 31 and 32 can be used with VDEAL. Only VCP 121, which provides data to the MPDA, cannot be used with VDEAL.

6.5 VDEAL and PRF Selection

Normally, the Auto PRF function will satisfactorily maximize echo coverage, but sites may opt to use a PRF other than the one selected by the Auto PRF function to improve coverage in a certain sector of the coverage area. PRFs 4 through 8 may be used with VCPs 11, 12, 21, and 32. For VCPs 211, 212, and 221 the split cuts are hard-wired to use PRFs 8, 6, and 4, respectively, but above 1.5 deg elevation PRFs 4 through 8 may be used.

Please note that VDEAL is not designed to run with sectorized PRFs. If a site chooses to sectorize PRFs, the ORPG velocity dealiasing software will revert to the legacy VDA. Whenever the PRF is reset to be the same for all sectors, the 2D VDEAL will again become the active dealiasing algorithm if it has already been enabled.

6.6 VDEAL and Range Folding

VDEAL does not reduce range folding so operational users will need to maintain situational awareness to ensure weather features of interest are not obscured.

6.7 VELDEAL and CPU Usage

The 2D VDEAL algorithm makes heavy use of the RPG's 2 CPUs. While the ROC has conducted extensive testing VDEAL in a variety of weather phenomena, there exists the remote possibility of a task failure. Besides a task failure message being sent to the RPG Status log, a site would note the absence of new products.

Remedial Action: From the HCI Control window disable the 2D VELDEAL algorithm, and then restart the RPG. At soon as is convenient notify the Test Director, Deputy Director, or the ROC Hotline of the incident. (See Section 9. Coordination and Communication)

7. ROC Evaluation of VDEAL

As resources permit, the ROC will run both the legacy VDA and the 2D VDEAL simultaneously from ldm Level 2 data feeds for each site especially during important weather events. We will tabulate the frequency of velocity dealiasing errors observed with each algorithm as part of the final report.

8. Site Questionnaires

There will be three separate web-based questionnaires. An initial questionnaire at the start of the field test, a recurring questionnaire during the field test, and an exit questionnaire at the end of the field test. Links to the 3 questionnaires may be found at the ROC's web site show below. To access the questionnaires a user will enter his/her email address and password.

http://www.roc.noaa.gov/WSR88D/NewRadarTechnology/NewTechDefault.aspx

8.1 Initial Questionnaire

The first questionnaire will be completed once after a site has installed the software changes that enable 2D VDEAL and had a short check-out period. It will ask participating sites questions about how VDEAL works and if they feel they have had sufficient training. Questions will be drawn from material presented in this document.

8.2 Recurring Questionnaire

A second questionnaire will be completed by sites if they observe velocity dealiasing errors with VDEAL or after a major weather event such as a hurricane. This questionnaire will help us (ROC) to get a feel for the level of satisfaction/comfort a site has using VDEAL or if they chose not use VDEAL was there a particular reason. Sites will be asked to describe the nature of dealiasing errors observed. Section 9 provides guidance on the recognition and interpretation of errors.

8.3 Exit Questionnaire

The third questionnaire will be administered after the field test is concluded and will ask sites to rate the performance of VDEAL as fully successful, somewhat successful, or not at all successful. We ask each participating site to provide one response to represent the overall satisfaction with VDEAL. The rating system follows that defined in the ECP-0511 Test Plan. This latter questionnaire will be important in determining how VDEAL is fielded. That is, will it 1) replace the existing VDA, 2) be provided as an alternative dealiasing scheme for certain weather events, or 3) not fielded at all because it provides no operational improvement over the existing VDA.

9. Coordination and Communication

Prior to the start of the field test, email will be the primary mode of communication with participating sites focal points and Dave Zittel, Test Director, or Rich Murnan, Alternate Test Director especially as site reconfigure their RPG to run VDEAL. Telephoning may be used to deal with site-specific issues. During the field test sites will be encouraged to (but not required to) use the NWS rocchat room to communicate with each other and with the test directors.

After a significant weather event the test directors may request a site complete the recurring questionnaire about the quality of velocity dealiasing during the event.

If operational users encounter a problem using the 2D VDEAL after 5 p.m. or before 8 a.m. they should contact the Radar Operations Center's Hotline for assistance. The Hotline will consult with the test director if there are problems that cannot be resolved. During regular hours field sites may contact the test directors directly for assistance with 2D VDEAL issues.

W. David Zittel, Test Director
walter.d.zittel@noaa.gov
david12330@gmail.com
(405) 325-2187 (work)
(405) 834-8764 (cell)

Rich Murnan, Alternate Test Director
Richard.L.Murnan@noaa.gov

(405) 325-2567 (work)

10. Examples of Velocity Dealiasing Errors

Although the atmosphere doesn't allow for zero or first order discontinuities, the limitations of discrete sampling will give the appearance of such type of discontinuities. In velocity data this type of discontinuity is most strikingly observed in circulations and along outflow boundaries. Velocity dealiasing algorithms sometimes propagate such discontinuities either azimuthally or along radials especially when dealiasing using low Nyquist velocities. (The Nyquist velocity is the maximum positive or negative velocity the radar can measure without becoming aliased.) These errors may visually present themselves as spikes, wedges, or patches. (See Table 1 below.) VCP 31, with a Nyquist velocity of ~11 m/s, is especially prone to these types of dealiasing errors. Another source of errors is from moving clutter such as turbines from wind farms or vehicular traffic and may show up as very small patches or a few bins that don't fit the ambient flow. A difficult type of velocity dealiasing error to recognize is an isolated region that has no discontinuities but is off by two times the Nyquist velocity.

As it is very unlikely that any velocity product is completely free of velocity artifacts, sites should focus on obvious errors or errors that are of operational significance.

Table 1: Different types of dealiasing errors (Adapted from Witt et al. 2009).

Description of Error	Comment
Single gate or 2 adjacent gates	Appears as noisy velocity data
Small radial spike (<3 km in length)	Spans 1 to 3 radials
Large radial spike (> 3 km in length)	Spans 1 to 3 radials
Very small patch (~1 km in diameter)	Irregular shape
Small patch (~3 to 10 km in diameter)	Irregular shape
Large patch (> 10 km in diameter)	Irregular shape
Small wedge <20°	Radially-aligned discontinuity
Medium wedge of ~40°	Radially-aligned discontinuity
Large wedge of ~60°	Radially-aligned discontinuity
Very large wedge of ~90° or larger	Radially-aligned discontinuity

A companion set of slides (in PDF format) illustrates the types of dealiasing errors that can occur. Although VDEAL has fewer dealiasing errors than the legacy VDA, errors are still possible. Some examples of errors from VDEAL are also provided. The link to the dealiasing error slides follows:

http://www.roc.noaa.gov/WSR88D/NewRadarTechnology/NewTechDefault.aspx